Vol.48, n. 3 : pp. 335-342, May 2005
ISSN 1516-8913 Printed in Brazil

BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY
AN INTERNATIONAL JOURNAL

Effect of Polymers Associated with N and K Fertilizer Sources on *Dendrathema grandiflorum* Growth and K, Ca and Mg Relations

Regiane Cristina Marcato Sita[1], Carlos Bruno Reissmann[2*], Renato Marques[2], Edilson de Oliveira[3] and Angela Daniela Taffarel[2]

[1]Curso de Pós-Graduação em Ciência do Solo; Universidade Federal do Paraná; [2]Departamento de Solos e Engenharia Agrícola; Rua dos Funcionários, 1540; 80035-050; Curitiba -PR - Brazil. [3] CNPF/EMBRAPA; C. P. 319, 83411-000; Colombo - PR - Brazil

ABSTRACT

This study was conducted to evaluate the effect of polymer used with different nitrogen and potassium sources on the growth and nutrition of chrysanthemum (Dendranthema grandiforum, var. "Virginal") and on chemical characteristics of substrate. Two substrates were evaluated: 1) composite with 50 % organic soil, 45 % sand, and 5 % composted tobacco; 2) plow layer soil (0-20 cm depth; red oxisol typical dystrophic). The experimental design was a factorial (4x2x2) and included four polymer rates (0, 1, 2, and 4 g kg^{-1} of substrate), two nitrogen ($(NH_4)_2SO_4$ and $(H_2N)_2CO$), and two potassium (KCl and K_2SO_4) sources. Dry biomass, flower number, and concentration of K, Ca, and Mg were evaluated. Inverse relationships between polymer rates and plant biomass, macronutrient uptake were noticed, regardless substrate or nutrient source.

Key words: Hydrogel, polyacrylamide, chrysanthemum, fertilizer, macronutrients

INTRODUCTION

An expressive number of studies have been developed searching for better substrates and soil conditioners for plant production. Agricultural polymers are preferentially used in seedling, flower, and vegetables crops aiming better conditions for water availability (Bassiri et al., 1986). The increase of water retention in the soil promotes an increase in germination of seeds, reduces water and nutrient losses, diminishes irrigation and management costs. Besides adsorbing water and improving the physical properties of the soil, polymers are capable to absorb and adsorb fertilizers in their structure acting as a typical colloid due to its hydrophilic characteristics and the presence of negatively charged functional groups. The presence of Ca and Mg and ionic ferric forms in irrigation water causes a deterioration of the gel reducing its water retention capacity. This general effect indicates that multi charged cations display and substitute water in the polymer framework at the polarized sites (Johnson, 1984a; James and Richards, 1986). Despite a significant number of studies reporting about polymer utilization as agricultural alternatives, the greatest part of the investigations are related to the water retention capacity. Studies showing interactions of polymers with substrate and fertilizers are scarce and not conclusive.

* Author for correspondence

Due to previous observations in flower production farms, where negative results were detected in relation to organic substrates, polymer and fertilizer combinations, a complex experiment had to be planned. In this sense, this study is part of a research aiming a better understanding about polymers and fertilizer interactions focusing soil chemical characteristics and plant nutrition. Despite a complete analysis of the study materials, including different polymer contents, macro and micronutrients (Sita, 2002), only interactions of K, Ca, Mg and EC (Electrical conductivity) are discussed in this text. A commercial substrate added with different polymer rates was used in the presence of urea, ammonium sulfate, potassium chloride and potassium sulfate. To measure the effects on plant development, chrysanthemum plants, were cultivated in pots containing the different treatment mixtures.

MATERIALS AND METHODS

The experiment was installed in a greenhouse at Conspizza Hidrossemeadura Ltd., Colombo County, Curitiba-PR, in the summer of 2001. The experimental lay out was a randomized block design with factorial treatment 4 x 2 x 2. Four levels of polymer: 0, 1, 2 and 4 g kg^{-1} substrate were established and combined with two sources of N (Urea and Ammonium Sulfate) and two sources of K (Potassium Chloride and Potassium Sulfate) for each elaborated substrate being locally identified as substrate 1 and 2, resulting in 160 experimental units. Chrysanthemum seedlings, *Dedranthema grandiflorum* var. virginal, obtained from "Agro-industrial Valentino Ltd., LAZZARI Agricultural Group", were planted one per pot as test plant. Substrate 1 was an elaborated mixture containing the following proportions: 300 kg medium organic rich soil (C_{org} > 2.5%), 270 kg fine sand and 30 kg composted tobacco residues. Chemical and physical characteristics are presented on Table 1. Substrate 2 corresponded to the superficial layer (0-20cm) of an Oxisol (LATOSSOLO VERMELHO Distrófico típico), located at Embrapa Experimental Station-Ponta Grossa County-PR. Chemical and physical characteristics are presented on Table 2. Both substrates were analysed at the Soil and Agricultural Engineering Department of the Federal University of Paraná. According to their characteristics, substrate 1 and 2 received distinct fertilizations (Raij et al., 1996).

Table 1 - Chemical and physical characteristics of substrate 1

P	K	Ca	Mg	Al	CEC[1]	C	pH	EC[2]	BS[3]	Sand	Silt	Clay
mg dm^{-3}	$cmol_c$ dm^{-3}					g dm^{-3}	$CaCl_2$	dS/m	%			
70,4	5,44	6,1	3,4	0	19,24	30,5	5,9	1,07	77,6	56	16	28

[1] CEC = Cation Exchange Capacity; [2]EC = Electrical conductivity; [3] BS = Base saturation

Table 2 - Chemical and physical characteristics of substrate 2

P	K	Ca	Mg	Al	CEC[1]	C	pH	EC[2]	BS[3]	Sand	Silt	Clay
Mg dm^{-3}	$cmol_c$ dm^{-3}					gdm^{-3}	$CaCl_2$	dS/m	%			
0,4	0,14	1,0	0,6	1,0	8,44	18,4	4,2	0,18	20,6	52,4	17,6	30

[1] Cation Exchange Capacity; [2]EC= Electrical conductivity; [3] Base saturation

For substrate 1, respective amounts of N, P and K corresponding to a fertilization formula of 30 100 50 kg ha^{-1} were added. For substrate 2, a corresponding amount of 60 300 150 kg ha^{-1} was applied. Only substrate 2 received liming treatment to achieve 80% base saturation (Raij et al., 1996). The pots containing 7 kg of substrate, received 0, 1, 2, 4 g kg^{-1} substrate of previously hydrated polymer (copolymer of acrylamide and acrylic acid). Fertilizers were added in the recommended amounts and combinations: ammonium sulfate/ potassium sulfate (SASK); ammonium sulfate/potassium chloride (SACK); urea/potassium sulfate (USK); urea/potassium chloride (UCK). Triple super phosphate was applied as basic complementary phosphorus fertilization. Treatment for diseases prevention were performed using insecticides and fungicides seven days after installation. Humidity control was performed by weighing the pots maintaining 2/3 of maximum water retention capacity with deionized water by top watering (Oliveira et al., 1991). Additional irrigation with complementary fertilizers, including micronutrients, was also performed according to flower producer recommendations during 12 weeks. At the end of this period, plants and substrates were sampled and prepared for respective analyses. K, Ca and Mg, in the shoots, previously dried at 60 °C for 72 hours, were obtained by dry ashing the aerial parts at 500 °C and brought in solution with 3 mol L^{-1} HCl. K was measured by flame emission and Ca and Mg by atomic absorption in a Strontium Chloride solution (Perkin Elmer, 1973). Both substrates, dried and sieved in a 2 mm sieve, were analysed according to the current methodologies: K, using Mehlich extraction (Thomas and Peaslee, 1973) and measured by flame emission; Ca and Mg extracted with 1 mol L^{-1} KCl, and measured by titration (EMBRAPA, 1979).

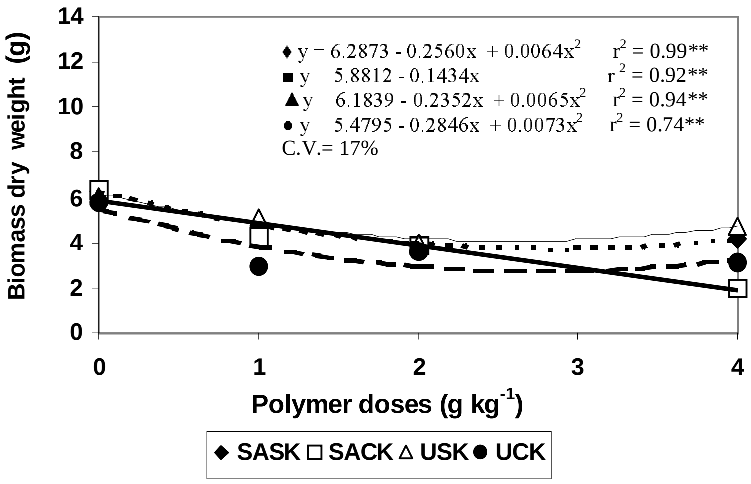

Figure 1 - Shoot dry biomass according to polymer levels in combination with N and K fertilizers in substrate 1.

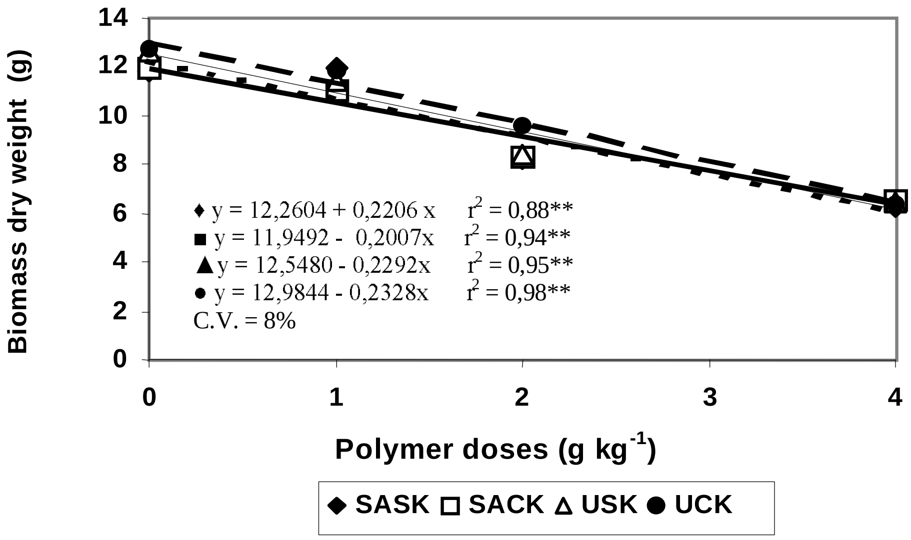

Figure 2. Shoot dry biomass according to polymer levels in combination with N and K fertilizers in substrate 2.

Electrical conductivity of the substrate extracts was measured according to Teem, (1986). Statistical evaluation was performed using the SANEST program (Zonta, Machado and Silveira, 1985).

RESULTS AND DISCUSSION

The results showed that the dry weight of above ground biomass diminished with increasing polymer content in the substrates (Fig. 1 and 2). The possible cause of this effect was probably a nutritional imbalance, or an inadequate combination of the fertilizers with the polymer. This fact should be more deeply investigated considering the susceptibility of the tested species. Some similar results have been observed for rye (*Secale cereale*) (Nissen and Tapia, 1996); Petunia(*Petunia sp*.) and Marigold (*Calendula sp*) (Lamont and O'Connel, 1987); *Codiaeum sp, Diffenbachia sp and Hibiscus rosasinensis* (Wang, 1989). According to Flannery and Usscher (1982), the polymer was also prejudicial to "Azalea". Bearce and Mccollum, referred by Azevedo (2000), reported an expressive gain in chrysanthemum biomass when grown in the presence of polymer in the substrate.

However the species of chrysanthemum was not reported. In the present investigation plants developed better on substrate 2, fundamentally elaborated from natural soil. This mean that substrate 1, elaborated from different material could have some detrimental component not already properly identified. K/Ca and K/Mg ratios in both substrates showed a crescent behavior in accordance with the polymer levels irrespective of the fertilizer source or combination (Table 3). It suggests a release of K from the polymer to substrate and may be related to the structural K of the polymer framework, which was formed from acrilamide and acrylic acid. As postulated by Viljoen (1997), these constituents are neutralized by K salts. Besides that, a decrease of Ca and Mg levels in the substrate was observed (Sita, 2002). It was due to its retention on the negatively charged sites of the polymer originated from the carboxylic groups present in its framework.

The strong attraction is possible due to ionic bond forces (Stockhausen Huels, 1995) referred by Delatorre et al., (not dated). Polymers own a strong capacity for fertilizer retention, especially those with divalent cations (Cottem, 1998). Hensley (2001) reported that substances like gels were able to adsorb Ca and Mg. Together with Fe they were responsible for the deterioration of the gel structure (Johnson, 1984; James and Richards, 1986). This general rupture effect of cations on the gel structure indicates that they possibly substitute the water molecules on the polarized sites. The bond should be strong enough to inhibit the dislocation by the extracting agent becoming lesser concentrated in the substrate solution. Routine analyses using 1 mol L^{-1} KCl for Ca and Mg extraction, as used for agricultural purposes, were possibly not efficient for organic and mineral mixtures of man made substrates, as it is common in beddings or greenhouse productions using many kinds of soil conditioners. As reported above, great amounts of K were detected in the extracting solution made up from diluted sulfuric and chloride acid. According to Cottem (1998), this is frequently observed. The possible more aggressiveness of the acids in relation to the salt extractant is not necessarily the cause for the higher amounts of K in the substrate, and higher amounts detected in the plant tissue also. This mean that higher amounts of K were already in solution and not only extracted through the chemical process developed in the laboratory. This support the theory that much of the K originated from the polymer.

The EC values (Table 3) were weakly affected by the treatments. The strongest evidence was observed on substrate 1 at the SACK treatment, where the EC showed a proportional increase to the polymer doses reaching a value of 2.4 at the highest rate. On the contrary, the lowest values were observed at the USK treatment in substrate 2 (Table 3). According to Teem (1986), values between 1.72 and 2.40 dS/m, as detected on substrate 1 for the SACK treatment, would be classified as moderately saline and could injury the plants. This author suggests that natural soil substrates should present an EC around 0.81 and 1.20dS/m, when grown plants in greenhouses. In this sense, only treatment USK on substrate 2 would fulfill completely this recommendation. There was a clear evidence that top watering, as performed on the present study, with permanent maintenance of 2/3 maximum water retention capacity, was not always recommendable considering an increase in salt retention in the pots as a result of absent percolation. In the plant tissues, K/Ca and K/Mg ratios were affected by crescent rates of polymer in both substrates (Fig. 3, 4, 5, 6).

Table 3 - Effect of polymer levels on E C, K/Ca and K/Mg ratios for substrates 1 and 2.

Substrate 1								
	K/Ca Ratio				K/Mg Ratio			
*Pol. (g kg^{-1})	$SASK_1$	$SACK_2$	USK_3	UCK_4	$SASK_1$	$SACK_2$	USK_3	UCK_4
0	0.57	0.59	0.56	0.59	1.09	1.13	1.10	1.06
1	0.56	0.63	0.64	0.64	1.17	1.20	1.19	1.22
2	0.70	0.65	0.68	0.61	1.36	1.53	1.49	1.48
4	0.81	0.80	0.88	0.80	1.89	1.94	2.04	1.95
Substrate 2								
	K/Ca Ratio				K/Mg Ratio			
*Pol. (gkg^{-1})	$SASK_1$	$SACK_2$	USK_3	UCK_4	$SASK_1$	$SACK_2$	USK_3	UCK_4
0	0.07	0.08	0.09	0.09	0.13	0.11	0.14	0.16
1	0.19	0.19	0.20	0.20	0.25	0.24	0.26	0.25
2	0.37	0.31	0.29	0.31	0.44	0.37	0.40	0.35
4	0.55	0.54	0.61	0.52	0.64	0.83	0.81	0.87
Electrical conductivity (EC)								
	Substrate 1 (dS/m)				Substrate 2 (dS/m)			
*Pol.. (g kg^{-1})	$SASK_1$	$SACK_2$	USK_3	UCK_4	$SASK_1$	$SACK_2$	USK_3	UCK_4
0	1.35	1.38	1.23	1.36	1.04	1.17	0.76	1.23
1	1.31	1.42	1.23	1.42	1.16	1.12	0.91	1.23
2	1.57	1.72	1.40	1.59	1.24	1.26	0.96	1.40
4	1.75	2.40	1.54	1.59	1.44	1.45	1.17	1.54

NOTE: pol*=polymer; (1) Ammonium Sulfate/Potassium Sulfate; (2) Ammonium Sulfate/Ammonium Chloride; (3)Urea/Potassium Sulfate; (4) Urea/ Potassium Chloride. This notation is also used on the other tables and figures.

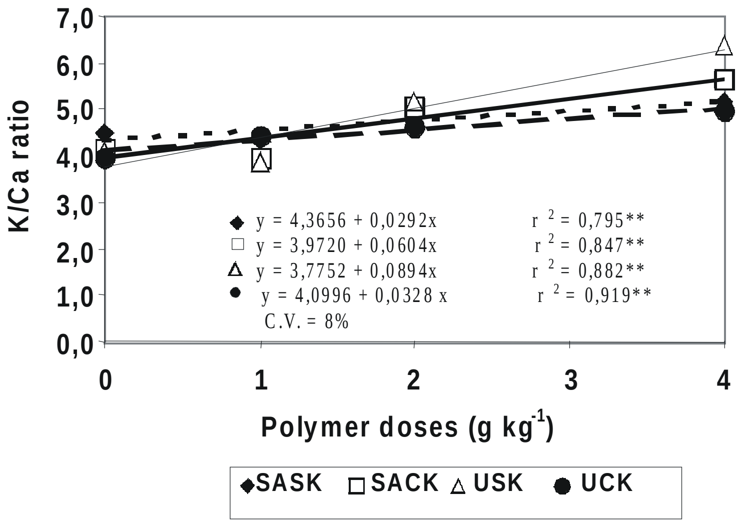

Figure 3 - K/Ca ratio in shoot biomass in relation to polymer levels in substrate 1.

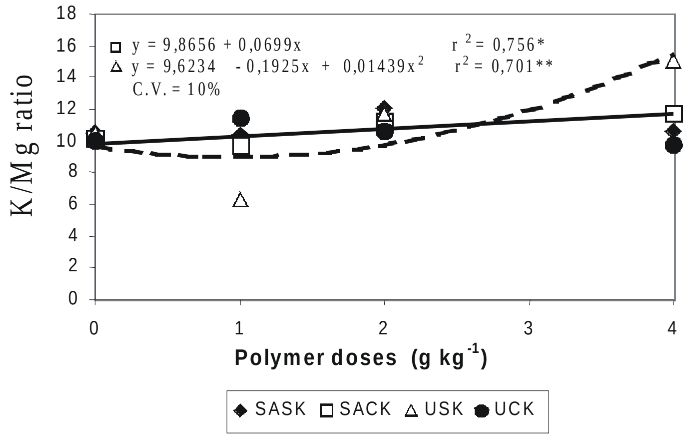

Figure 4 - K/Mg ratio in shoot biomass in relation to polymer levels in substrate 1.

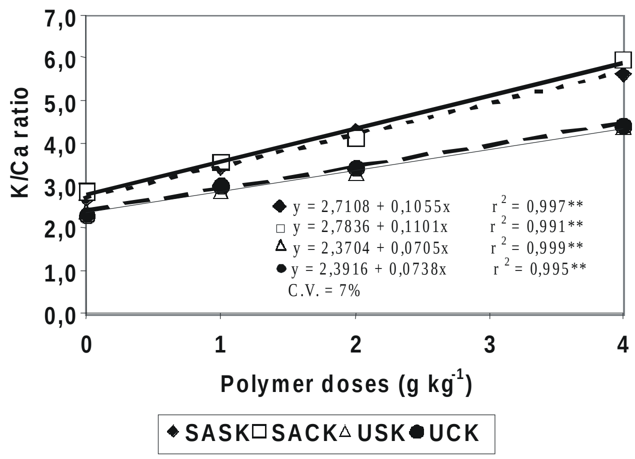

Figure 5 - K/Ca ratio in shoot biomass in relation to polymer levels in substrate 2.

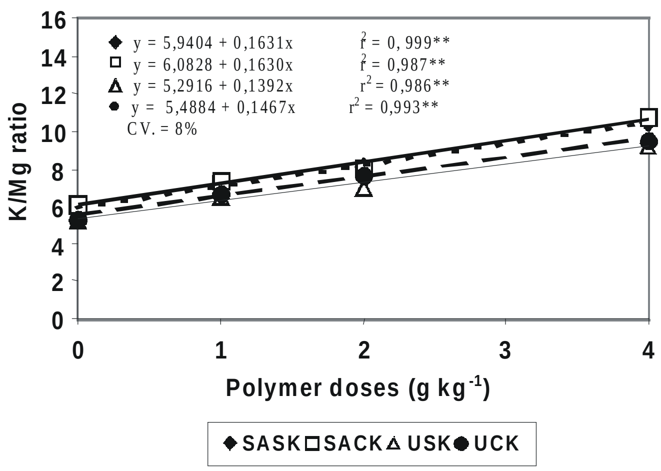

Figure 6- K/Mg ratio in shoot biomass in relation to polymer levels in substrate 2.

In all cases, the ratios increased with increasing polymer doses, meaning that more K were available for absorption with a detrimental effect on Ca and Mg availability due to its possible retention in the gel framework (Hensley, 2001). Similar results were reported by Wallace et al. (1986) for tomatoes and wheat. In their observations the soil conditioner decreased the concentration of K, Ca and Mg in the plant, while that of Na increased. In the present study, the decrease of K, Ca and Mg was a consequence of the anionic affinity of the polymer. For Ca, another explanation, however, needed be mentioned. Through visual observations it was noticeable that the fine root renewal was rather expressive. Considering that much of the Ca could be taken up by the new root tips without any expense of energy by mass flow (Marschner, 1995), this could at least partly explain the lowering in Ca absorption also.

CONCLUSIONS

The use of increasing levels of the polymer influenced directly plant development and the absorption of Ca and Mg ions. This effect was more prominent on substrate 1, elaborated from different materials as described above. Probably these ions were retained in the polymer framework, while releasing more K in solution. The weaker development of the plants could be attributed to a high EC, detected in the substrate solution. Further studies on the subject, especially on the organic and mineral mixtures of man made substrates, are recommended considering the great variability of materials and plant species susceptibilities.

RESUMO

O polímero agrícola tem um grande potencial de uso como condicionador de solo para produção de mudas. Contudo, pouco conhecimento existe sobre seu uso e interação com fertilizantes.Visando avaliar o efeito do polímero com diferentes fontes de abubações nitrogenadas e potássicas, no crescimento e nutrição do crisântemo (var. "Virginal") e características químicas dos substratos, um experimento foi montado. A instalação foi em casa de vegetação da Empresa CONSPIZZA HIDROSSEMEADURA Ltda., situada no município de Colombo-PR, no verão de 2001. Dois substratos foram testados: 1) composto de 50% de solo orgânico, 45% de areia e 5% de fumo compostado; 2) camada superficial (0-20cm) de um LATOSSOLO VERMELHO Distrófico típico, do município de Ponta Grossa. O delineamento experimental foi em blocos ao acaso, com 5 repetições, em esquema fatorial 4x2x2, sendo 4 doses de polímero (0; 1; 2 e 4g kg^{-1} de substrato), 2 fontes nitrogenadas [$(NH_4)_2SO_4$ e $(H_2N)_2CO$] e duas fontes potássicas (KCl e K_2SO_4), respectivamente. Determinou-se massa seca de ramos, folhas e teores de K, Ca e Mg. Os substratos foram avaliados quanto aos teores de K, Ca , Mg, valores de pH e condutividade elétrica (CE). Foram observados relações inversas entre doses de polímero e biomassa, absorção de K, Ca e Mg independente do substrato e fonte de fertilizante. Com exceção do K solúvel, cujos valores foram maiores em até 5 vezes em relação à testemunha, as demais características químicas do solo foram pouco afetadas. Foi observado um ligeiro aumento na CE, com o aumento nas doses de polímero em ambos os substratos. No substrato-1 os teores de todos os nutrientes analisados foram superiores aos observados no substrato-2. Mas, contrariamente, o crescimento das plantas foi melhor no substrato-2, indicando um provável desbalanço nutricional, principalmente associado às relações K/Ca e K/Mg. É possível também que o meio de crescimento do substrato 1 apresentava alguma característica não detectada que desfavoreceu o desenvolvimento da espécie testada. O polímero afetou negativamente a absorção de nutrientes e produção de biomassa, mas contribuiu substancialmente com o aumento de K nos substratos. Sugere-se novas pesquisas envolvendo outras espécies e substratos.

REFERENCES

Anjos, A. (1991), Estudo do calcário da formação Irati-São Mateus de Sul, PR como corretivo da acidez do solo. Curitiba, Dissertação (Mestrado em Agronomia) - Setor de Ciências Agrárias, Universidade Federal do Paraná.

Azevedo, T. L. F. (2000), Avaliação da influência do polímero agrícola de poliacrilamida no fornecimento de água para o cafeeiro (*Coffea arabica* L.) cv. Tupi. Maringá. 38 f. Dissertação (Mestrado em Agronomia) - Universidade Federal de Maringá.

Baasiri, M.; Ryan, J.; Muckeih, M. and Harih, S. N. (1986), Soil application of a hydrophilic conditioner in relation to moisture, irrigation frequency and crop growth. *Soil Science*, **17**, 573-589.

Bearce, B. C. and McCollum, R. W. A (1998), comparison of peat-lite and non-composed hardwood-bark mixes for use in pot and bedding-plant production and the effects of a new hydrogel soil amendment on their performance. (on line). Virginia, 1993. Avaiable from: http://www.hydrosource.com

Bowman, D. and Evans, R. Y. (1991), Calcium inhibition of polyacrylamide gel hydration is partilly reversible by potassium. *HortScience*, **26** : (8), 1063-1065.

Bremner, J. M. and Mulvaney, C. S. (1982), Nitrogen-total. In: Methods of soil analysis: part 2. Madison: SSSA/ASA. pp. 595-624.

Cotthem, L. V. (1998), *O papel de TerraCotten como um adsorvente*. Ghent: Universidade de Ghent. Relatório de aplicação.

Cuquel, F. L.; Granja, P. and Minami, K. (1992), Avaliação do enraizamento de estacas de crisântemo (*Chrysanthemum morifolium* L.) cv. White reagan 606 tratadas com ácido indólbutírico (IBA). *Scientia Agricola*, **1**: (49), 15-22.

Dehgan, B.; Yeager, T. H. and Almir, F. C. (1994), Photinia and podocarpus growth response to a hydrophilic polymer-amended medium. *Horticultural Science*, **29** : (6), 641-644.

Delatorre, J.; Lanino, M.; Poblete, I. and Moll, W. [S. d.]. *Efecto de la aplicación de poliacrilamidas en suelo desérticos sobre los requerimientos hidricodel algodón (*Gossypium hirsutum*)*. [S.l.: s.n.].

Embrapa. Serviço Nacional de Levantamento e correção de solos (1979), *Manual de métodos de análise de solo.* Rio de Janeiro. pp. 271.

Flannery, R. L. and Busscher, W. J. (1982), Use of a synthetic in potting soil to improve water holding capacity. *Commun. in Soil Sci. Plant Ann*., **13** : (2), 103-111.

Hensley, D. (2001), *Fertilizer effects*. Avaiable at: http://www2.ctahr.hawaii.edu/depart/tpss/digest/. Assed at: 22 abr. 2002.

Jackson, M. L. (1958), Soil chemical analysis. New York : Prentice Hall. pp. 498.

James, E. A. and Richards, D. (1986), The influence of iron source on the water-holding properties of potting media amended with water-absorbing polymers. *Scientia Horticulturae*, **28** : (3), 201-208.

Johnson, M. S. (1984a), Effects of soluble on water absorption by gel-forming soil conditioners. *Sci. Food Agric*., **35**, 1063-1066.

Johnson, M. S. (1984b), The effects of gel-forming polyacrylamides on moisture in sandy soils. *Sci. Food Agric*., **35**, 1196-1200.

Lamont, G. P.and O'Connell, M. A. (1987), Shelf-life of bedding plants as influence by potting media and hydrogels. *Scientia Horticulturae*, **31**, 141-149.

Marschner, H. [S. d.], *Mineral nutrition of higher plants.* London, New York : Academic Press. 889 pp.

Oliveira, A. J.; Garrido, W. E.; Araujo, J. D. and Lourenço, S. (Coords.) (1991), *Métodos de pesquisa de Fertilidade do Solo.* Brasília : EMBRAPA/SEA. pp. 196-197.

Perkin and Elmer (1973), *Analytical methods for atomic. absorption spectrophotometry*: analysis of feeds. Norwalk : Perkin Elmer.. Chapter AY-11.

Prevedello, B. M. S. and Reissmann, C. B. (2002), Nutrição mineral de plantas. In: Wachowicz, C. M. and Carvalho, R. I. N. (Orgs.). *Fisiologia vegetal*: produção e pós-colheita. Curitiba : Champagnat. pp. 115-134.

Raij, B.; Cantarella, H.; Quaggio, J. A. and Furlani, A. M. C. (1996), *Recomendação de Adubação e Calagem para o Estado de São Paulo*. 2. ed. Campinas : Instituto Agronômico and Fundação IAC. (Boletim Técnico; 100).

Teem, D. H. (1986), *Procedures used for soil and plant anlysis by the Auburn University soil testing laboratory*. Alabama : Auburn University. (Departmental series; 106).

Thomas, G. W. and Peaslee, D. E. (1973), Testing soil for phosphorus. In: Walsh, L. M. and Beaton, J. D. *Soil testing and plant analysis*. Madison : Amer. Soc. Agron. pp. 115-132.

Viljoen, D. J. (1997), “Superabsorbent” polymers in the forestry industry. In: Commonwealth Forestry Conference, 15., Victoria Falls. *Proceedings...* Victoria Falls. pp. 1-12.

Wallace, A.; Wallace, G. A.; Abouzamzam, A. M. and Cha, J. W. (1986), Soil tests to determine application rates for polymeric soil conditioners. *Soil Science*, **141** : (5), 390-394.

Received: October 17, 2003;
Revised: May 06, 2004;
Accepted: December 28, 2004.